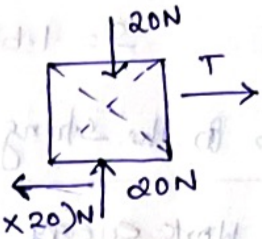
Consider 20N block,

Freebody diagram of 20N weight:



Workdone = Net force × Distance

$= \{T - (0.3 \times 20)\} s$

$= (T-6) s \rightarrow (1)$

Change in kinetic energy $= \frac{W}{2g}(v^2 - u^2)$

$(u = 0 ; v^2 = 1.962 s) = \frac{20}{2 \times 9.81}(1.962 s - 0) \rightarrow (2)$

Equating (1) and (2) we get

$(T-6) s = \frac{20}{2 \times 9.81}(1.962 s)$ (or) $T - 6 = 2$

$\therefore T = 8$ N

Two blocks A and B of weight 120N and 100N are hung to the ends of a rope, which is passing over an ideal pulley. The velocity of the system is increased from 1 m/s to 2 m/s. How much the distance, these blocks will move? Also calculate the tension in the string? use work - energy method.

Solution:

When the system is released 120N block will move downwards and 100N block will move upwards.

Hence, workdone by the system is $(120 - 100 s)$

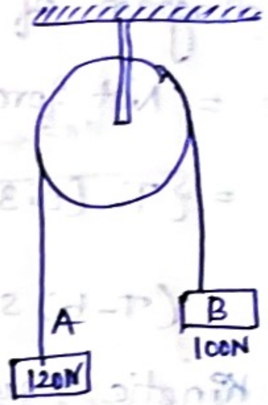
change in kinetic energy of the system is $\frac{W_1 + W_2}{2g}(v^2 - u^2)$

Applying work - energy equation, we get

$(120 - 100) s = \frac{120 + 100}{2 \times 9.81}(2^2 - 1^2)$ $(\because u = 1$ m/s, $v = 2$ m/s$)$

$$20s = 11.21(4-1)$$

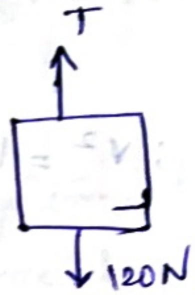
$$s = 1.681\,m$$



Tension in the string

Apply work energy equation on 120N block

Let T be tension in string.



$$\text{Workdone} = (120-T)s$$

$$\text{Change in K.E} = \frac{W}{2g}(v^2-u^2)$$

$$(120-T)s = \frac{W}{2g}(v^2-u^2)$$

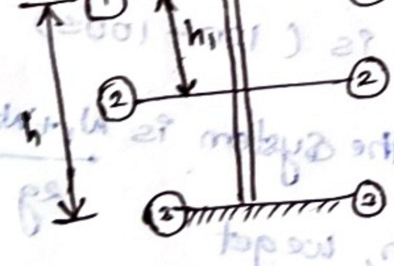
$$(120-T)\times 1.681 = \frac{120}{2\times 9.81}(2^2-1^2)$$

$$\boxed{T = 109.09\,N}$$

Conservation of Energy :-

↳ This law states that the energy can neither created nor destroyed, but it may change its form and may get converted into another form of energy.

i.e Total energy possessed by a ~~body~~ body remains same.



Level ① Body at rest

$P.E = mgh \quad K.E = 0$

$T.E = P.E + K.E$

$\boxed{T.E = mgh}$

level ② (h_1 from top of Tower)

$P.E = mg(h - h_1)$

$K.E = \frac{1}{2}mv^2$

$v = v_2$

$K.E = \frac{1}{2}mv_2^2$

Find velocity v_2 in terms of h

$v^2 = u^2 + 2gh$

$v = v_2 \quad h = h_1 \quad u = 0 \qquad v_2 = \sqrt{2gh_1}$

$v_2^2 = 0 + 2gh_1$

$K.E = \frac{1}{2}mv_2^2 = \frac{1}{2}m \times 2gh_1 = mgh_1$

$T.E = P.E + K.E$

$= mg(h - h_1) + mgh_1$

$= mgh - \cancel{mgh_1} + \cancel{mgh_1}$

$\boxed{T.E = mgh}$

level ③ (Body at ground)

$P.E = 0 \quad mgh = 0 \qquad (\because h = 0)$

$K.E = \frac{1}{2}mv_3^2$

$v^2 = u^2 + 2gh$

$v = v_3 \quad u = 0 \quad v_3^2 = 0 + 2gh \qquad v_3^2 = 2gh$

$K.E = \frac{1}{2}mv_3^2 = \frac{1}{2}m \times 2gh = mgh$

$\boxed{T.E = mgh}$

(1) A car of mass 300 kg is travelling at 36 kmph on level road. It is brought to rest after travelling a distance of 5m. What is the average force of resistance acting on car.

(1) From Conservation of Energy

mass, $m = 300\,kg$

$u = 36\,kmph = \frac{36 \times 1000}{3600} = 10\,m/s$

$v = 0$

distance travelled, $s = 5m$

Find the average resistance?

Force of resistance be 'F'

K.E of the moving car, $KE = \frac{1}{2}mu^2$

$= \frac{1}{2} \times 300 \times 10^2 = 15000\,Nm$

The moving car is bought to rest.

Whole K.E is lost at a distance of 5m.

K.E = Workdone by resistance

15000 = Resistance × distance

$15000 = F \times 5$

$\boxed{F = 3000\,N}$

Apply work energy method.

Workdone = change in KE

$(-F)s = \frac{W}{2g} \times (v^2 - u^2)$

$-F \times 5 = \frac{300 \times 9.81}{2 \times 9.81}(0 - 10^2)$

$F = 3000\,N$

$-F - ma = 0$

$\boxed{F = -ma}$

$v^2 = u^2 + 2as$

$0 = 10^2 + (2 \times a \times$

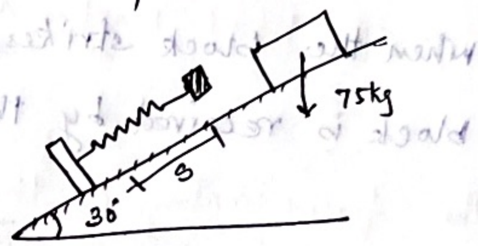
$a = \frac{-100}{10} = -10$

$F = -ma$

$= -300 \times ($

$= 3000N$

A block of mass 75 kg slides down a 30° inclined
ne from rest, as shown. After moving 1.2 m, the
ock strikes a spring whose modulus is 20 N/mm. Det
e max deformation of spring. Take coefficient of
kinetic friction b/w the block and plane is 0.25



→ max deformation of spring

→ velocity at which the block strikes.

Resolving the force normal to plane

$\cancel{N_R =}$ $N_R - (75 \times 9.81 \cos 30) = 0$

$N_R = 637.17\,N$

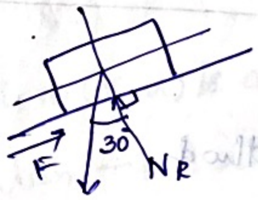
Resolving the force along the plane,

$\Sigma F_x = -(75 \times 9.81 \sin 30) + F$

$\Sigma F_x = \cancel{-(75\times} -(75 \times 9.81 \sin 30) + \mu N_R$

$= -208.58\,N$

$\Sigma F_x = 208.58\,N$



Second law of motion → Newton

$P = ma$

$a = P/m = \frac{208.58}{75} = 2.781\,m/s^2$.

$V^2 = u^2 + 2as \quad (u = 0)$

$V^2 = 0 + 2 \times 2.781 \times 1.2$

$V = 2.583\,m/s$

K.E of block

while striking the spring $K.E = \frac{1}{2} m v^2$

$= \frac{1}{2} \times 75 \times 2.538^2 = 250.19\ Nm$.

When the block strikes the spring, the entire K.E of block is received by the spring, which is equal to WD

K.E of block = Workdone by the spring

$250.19 = \frac{1}{2} K S^2$

$K = 20 N/mm$

$= 20 \times 10^3 N/m$

$250.19 = \frac{1}{2} \times 20 \times 10^3 \times S^2$

$S = 0.158 m$

$\boxed{S = 158\ mm}$

Impulse and Momentum :

Method	Suitability
D' Alembert's principle →	kinetic problem involving force and acceleration
Work energy method →	Kinetic problem involving force, velocity & displacement.
Impulse - Momentum method –	kinetic problem involving force, time and velocity

Impulse of a Force :- (I)

→ When a large force acts for short period of time that force is called an Impulsive force.

$$I = \int_{t_1}^{t_2} F\,dt$$

Linear Impulse = Force × Time.

Momentum : (kgm/s).

Momentum = mass × velocity

$$\boxed{M = mv}$$

Impulse - Momentum eqn :-

$$F = ma$$

$$= m \cdot \frac{dv}{dt}$$

$$\int F\,dt = \int v\,dv$$

$$\int F\,dt = \int m\,dv$$

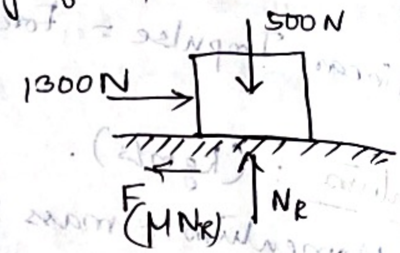
$$\int_{t_1}^{t_2} F\,dt = m\,[v]_u^v = m(v-u) = mv - mu.$$

The term $\int_{t_1}^{t_2} F\,dt$ is called impulsive and $m(v-u)$ is called change of momentum (i.e) Final momentum − Initial momentum :-

$$\text{Impulse} = m(v-u)$$

$$= \frac{W}{g}(v-u)$$

(P) A 500N block is in contact with a level plane, the coefficient of friction between two contact surfaces being 0.25. If the block is acted upon a horizontal force of 1300N, what time it will elapse before the block reaches a velocity of 24 m/s.



The forces acting on the block

$W = 500N$

$\mu = 0.25 \quad v = 24 m/s$

$N_R = 500N$

$F = \mu N_R$

$= 0.25 \times 500 = 125N$

Net force along the direction of motion

$\Sigma F = 1300 - F$

$= 1300 - 125 = 1175N$

Applying Impulse - Moment Eqn

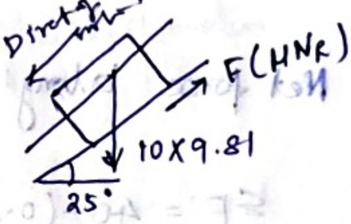
$\Sigma F \times t = m(v-u) \quad u = 0$ (at start) $v = 24$

$1175 \times t = \frac{500}{9.81}(24-0)$

$t = 1.04$ sec

(P) A 10 kg block slides down from rest on an inclined plane inclined at 25°, with the horizontal what will be speed of block at end of 3 sec. Take the coefficient of kinetic friction between the block and plane is 0.25

Resolving the forces normal to plane



$N_R - (10 \times 9.81 \cos 25) = 0$

$N_R = 88.9N$

Net force $\Sigma F = 10 \times 9.81 \sin 25 - F$

Force acts in direction of motion is taken +ve

$= \overset{98.1}{\cancel{9.81}} \sin 25 - (\mu N_R)$

$= 98.1 \sin 25 - (0.25 \times 88.9) = 19.23N$

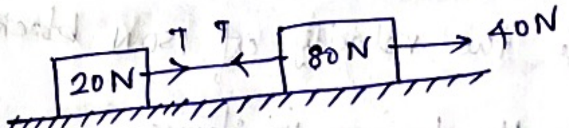
Apply ~~Impulsive~~ Impulse - Momentum eqn.

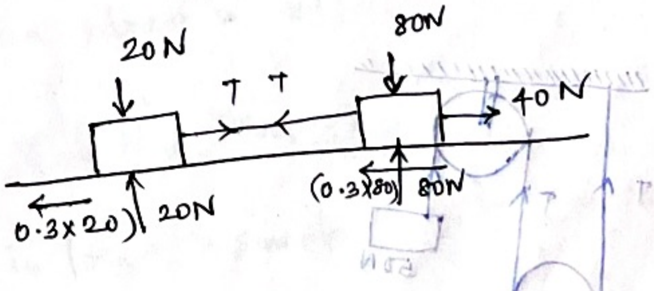
$\Sigma F \times t = m(v-u) \qquad (\because u=0)$

$19.23 \times 3 = 10(v-0)$

$v = 5.76 m/s$

(P) Two weights 80N and 20N are connected by a thread and move along a rough horizontal plane under the action of a force 40N, applied to the first weight of 80N as shown in diagram. The coefficient of friction between the sliding surfaces of weight and plane is 0.3. Determine the velocity of system after 2 sec. Also calculate the tension in the string using the impulse - momentum eqn.





Net force along the motion direction

$$\Sigma F = 40-(0.3\times 80) - (0.3\times 20) = 10N$$

applying impulse-momentum eqn

$$\Sigma F \times t = \Sigma m(v-u)$$

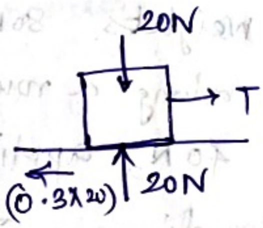
$$10\times 2 = \frac{20}{9.81}(v-0) + \frac{80}{9.81}(v-0) \qquad u=0$$

$$20 = \frac{20+80}{9.81}(v)$$

$$v = 1.962\ m/s$$

Tension in thread

consider 20N block (moving towards right)

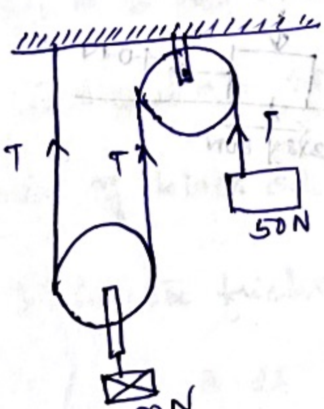


$$\{T-(0.3\times 20)\}t = m(v-u)$$

$$(T-6)\times 2 = \frac{20}{9.81}(1.962-0)$$

$$\boxed{T = 8N}$$

(P) Two blocks of weight 150N and 50N are connected by a string a passing over a frictionless pulley as shown as diagram. Determine the velocity of 150N block after 4 sec. Also calculate the tension in string

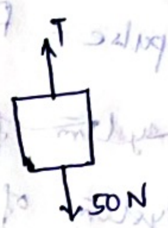


Consider 50 N

$T \rightarrow$ direction of motion $\rightarrow$ +ve

velocity = $2v$ $\quad u = 0 \quad t = 4$ sec

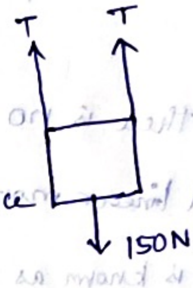
Applying Impulsive - Momentum eqn.



$$(T-50)t = \frac{50}{9.81}(2v - 0).$$

$$T - 50 = 2.548\,v \rightarrow (1)$$

Consider 150 N



Applying Impulsive - Momentum eqn

$$(150 - 2T)\,4 = \frac{150}{9.81}(v - u) \qquad u = 0$$

Tension T is in opposite direction of motion, hence it is -ve

$$(150 - 2T)\,4 = \frac{150}{9.81}\,v \rightarrow (2)$$

Solve (1) & (2) we get

$v = 5.6\ m/s$ (i.e) Velocity of 150 N block)

but velocity of 50 N is $2v = 2 \times 5.6$

$= 11.2\ m/s$

$T = 64.278\ N$

⇒ Velocities of blocks are not equal at any time

velocities of blocks are not equal at any time ⇒ When 150 N block moves downwards a distance 's'.

⇒ at same time 50 N blocks moves upwards a distance of 2s.

because 150 N block is supported by slings on both sides.

Conservation of Linear Momentum

↳ Loss of momentum of one body is equal to again of another body

$$\int F\,dt = m(v-u)$$

Impulse = Final momentum − Initial Momentum.

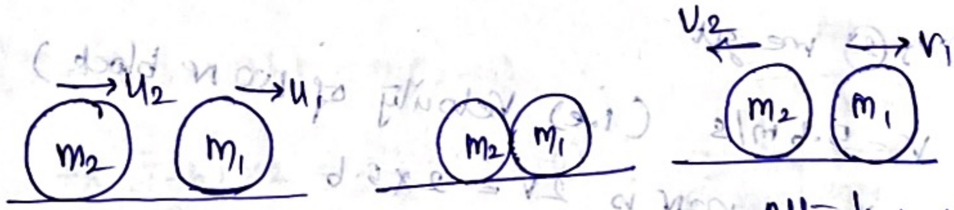
~~For a system of Particle~~

For system of force on a particle, impulse $= \Sigma F \times t$

When impulse is zero ; t can be zero and hence $\Sigma F = 0$.

If there is no external force acting on system then the total linear momentum of system remains constant". This is known as law of conservation of linear momentum

Initial momentum = Final Momentum.



Before impact   during impact   After impact

sum of ~~impact~~ momentum of two bodies ~~after~~ before impact } = sum of momentum of two bodies after Impact

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2 .$$